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**CHARACTERIZATION OF SOLID AND LIQUID
PROPELLANT IGNITERS FOR USE IN MEDIUM
CALIBER REGENERATIVE LIQUID PROPELLANT GUNS**

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<p>Two types of conventional igniters were characterized for use in a 30-mm regenerative injection liquid propellant gun. The characterization consisted of performing a series of tests in which the igniters were vented into a closed chamber. Pressure-time characteristics and the degree of repeatability were determined for the igniters. Both types of igniters are based on the use of a M52A3B1 (M52) electrical primer coupled to a booster charge consisting of either a solid propellant charge of IMR 4350 for one type of igniter, or a liquid propellant charge of LGP 1846 for the second type of igniter. Two designs were examined for the type with the solid propellant booster charge. The first design consisted of discharging the M52 into a bed of IMR 4350 rifle powder, part of which was constrained in a plastic soda straw. For seven tests the percentage variation in the standard deviation for the maximum closed chamber pressure was</p> <p style="text-align: right;">→ (7.9%)</p>					
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3.8%. The second design using a solid propellant charge consisted of discharging the M52 into a bed of IMR 4350 which was constrained only by the igniter housing. For this second design the percentage variation in the standard deviation for six tests, again for the maximum closed chamber pressure, was 2.6%. However, there was a significant degradation in the reproducibility for the time required to reach maximum pressure in the closed chamber. Several configurations were used for the second type of igniter which used a liquid propellant booster charge. For a group of five tests using a plastic seal to initially confine the liquid propellant, it was found that the percentage variation in the standard deviation for the maximum pressure recorded in the closed chamber was 13.7%. The tests with the liquid propellant for the booster charge showed that the type of packaging used for the liquid propellant is an important design concern.

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I. INTRODUCTION

The ignition of propellant charges, whether solid or liquid propellant, is a critical step which must be successfully implemented to avoid potentially serious problems. The ignition of solid propellant charges have been extensively studied over the years. A comprehensive review and potential problems have been given by East.¹ Problems which may arise during the ignition of solid propellant charges can also occur during the ignition of liquid propellant charges. For example, an under ignited charge may result in a hang fire or a misfire, while an over ignited charge may result in the generation of pressure waves in the gun chamber. The ignition of liquid propellant charges in regenerative injection liquid propellant guns (RLPGs) has not been extensively studied. This is due partly to the reasonable success which has been achieved with RLPG tests under well controlled conditions² and to the use of solid propellant igniter booster charges which can be easily adjusted according to readily computed data (i.e., mass burning rate knowing the web and propellant properties). The continued development of the RLPG will be aided, however, if simpler ignition systems are developed and if more of a fundamental understanding of the ignition process is obtained between the igniter output and the injected liquid propellant.

This study does not address the fundamental understanding of the ignition process; rather, it is concerned with characterizing the pressure output of igniters, and thereby provide a data base for an ignition system which has been successfully used in 30-mm RLPGs.³ The two functions the igniter must perform are (a) to generate sufficient gas to do work on the piston to start the injection process and (b) to provide sufficient energy to ignite the injected propellant to achieve sustained decomposition. The present study, therefore, is based on characterizing pyrotechnic type of igniters that are designed to satisfy the two required functions.

II. APPROACH

The approach consisted of characterizing the pressure output from an igniter that had been used in extensive testing of a 30-mm regenerative liquid propellant gun by the General Electric Ordnance Systems Division (GEOSD). This characterization included monitoring of pressure in both a closed chamber into which igniter gases vented and in the volume of the igniter where the electrical initiator, or primer, is vented into a cavity partially occupied with a solid propellant. The closed chamber was used to simulate the initial free volume in a 30-mm RLPG. The baseline results of this extensively tested igniter were compared to two other variations of initiator and solid propellant charge. The baseline tests were also compared to tests where the solid propellant charge was replaced by a charge of liquid propellant. The pressure generated in the igniter and the build-up of pressure in the closed chamber were recorded, in most cases, on a ballistic data acquisition system. The reduced data include maximum pressure, rate of pressure rise, and a 10-90% rise time for the closed chamber.

III. EXPERIMENTAL

Figure 1 illustrates the solid propellant igniter which has been successfully used in 30-mm RLPG tests performed at the GEOSD.³ The igniter shown in Figure 1, referred to as the reference igniter, consists of a M52A3B1 (M52) electrical primer, a 3.0 g booster charge of IMR 4350 smokeless powder, and a vent passage for coupling the output of the igniter to a closed chamber which simulates a 30-mm RLPG chamber. The internal volume of the igniter is 6.5 cm³ and the volume of the closed chamber is 106 cm³. Approximately 0.5 g of IMR 4350 was contained in a 6-mm diameter soda straw that was placed between the igniter vent passage and the primer vent hole. The IMR 4350 in the straw provided a reproducible way to place the solid propellant in the vent path of the M52 primer. The ends of the straw as well as the vent passage were initially sealed with wads of tissue paper. Piezoelectric pressure gages were mounted in the ignition chamber area containing the solid propellant charge and the closed chamber. The ignition chamber pressure revealed information on the pressure output coupling of the igniter and the solid or liquid booster charge, while the closed chamber pressure gage indicated the probable early pressure rise due to the igniter in a gun chamber.

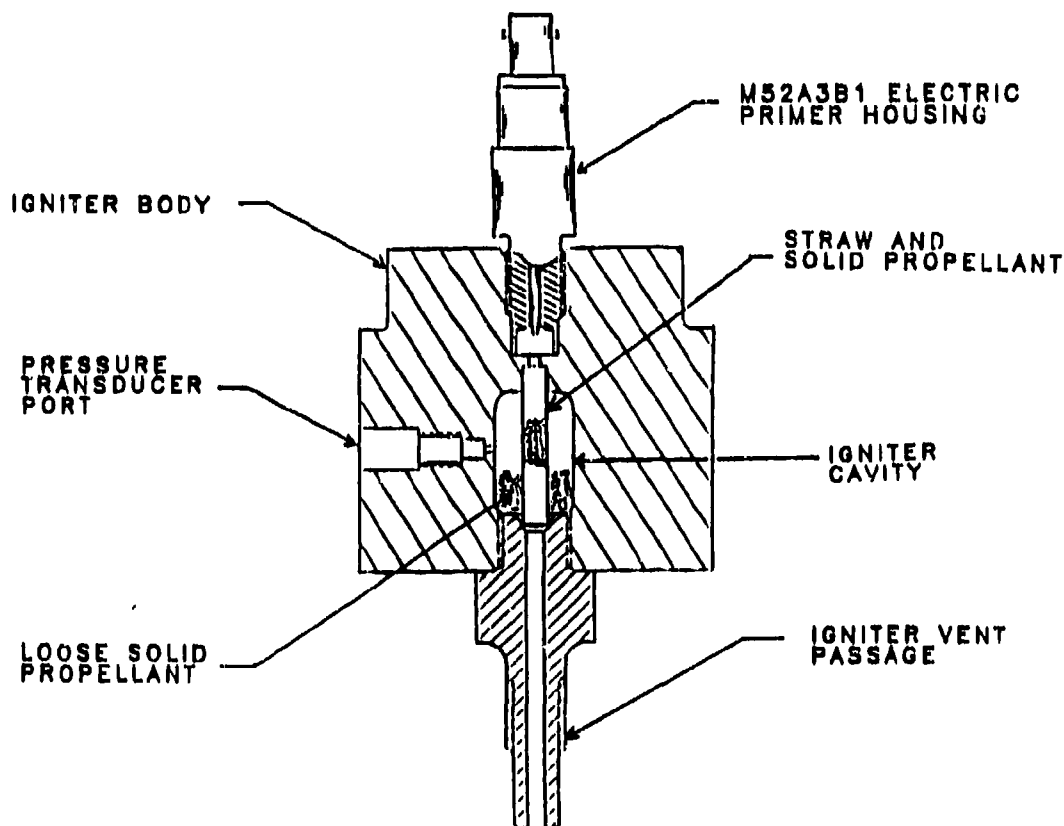


Figure 1. Solid Propellant Reference Igniter

IV. RESULTS

1. SOLID PROPELLANT BOOSTER CHARGE

The typical pressures generated by the reference igniter are shown in Figures 2 and 3. Figure 2 shows the pressure generated by the interaction of the M52 initiator and the solid propellant charge. The pressure shows a rapid increase as the igniter gases expand in the chamber followed by a more gradual decrease until equilibrium with the pressure in the closed chamber is achieved. Figure 3 is the pressure time curve of the 106 cm³ closed chamber that simulates the initial pressure on the regenerative piston and start of the propellant injection of the 30-mm gun. Seven tests were conducted using the reference igniter and the results are shown in Table 1. The lack of pressure data for Ident 21 of the igniter chamber was caused by a malfunction of the calibration of the ballistic data acquisition system. Of interest are the variations in the pressure recorded in the 106 cm³ chamber. The percentage variations in the standard deviation for the maximum pressure and the time to reach maximum pressure were, respectively, about 4% and 11%.

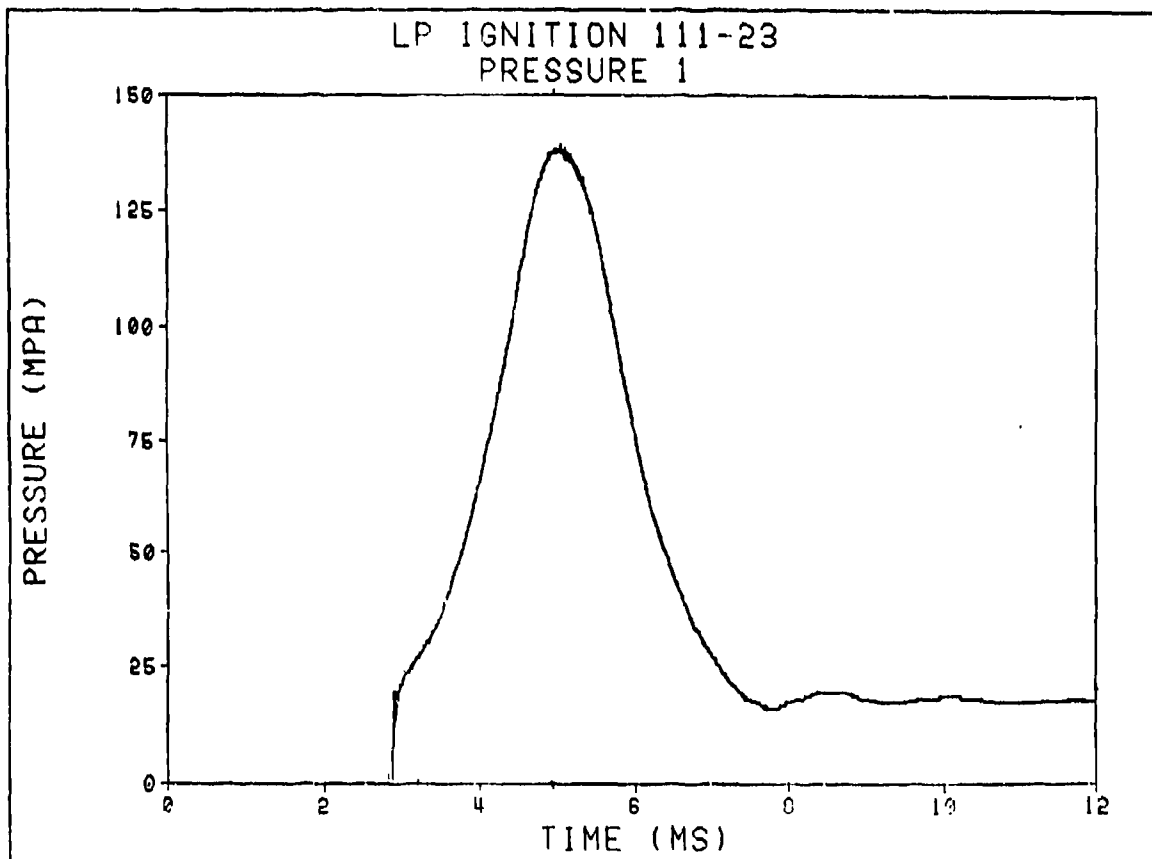


Figure 2. Igniter Chamber Pressure for Reference Igniter

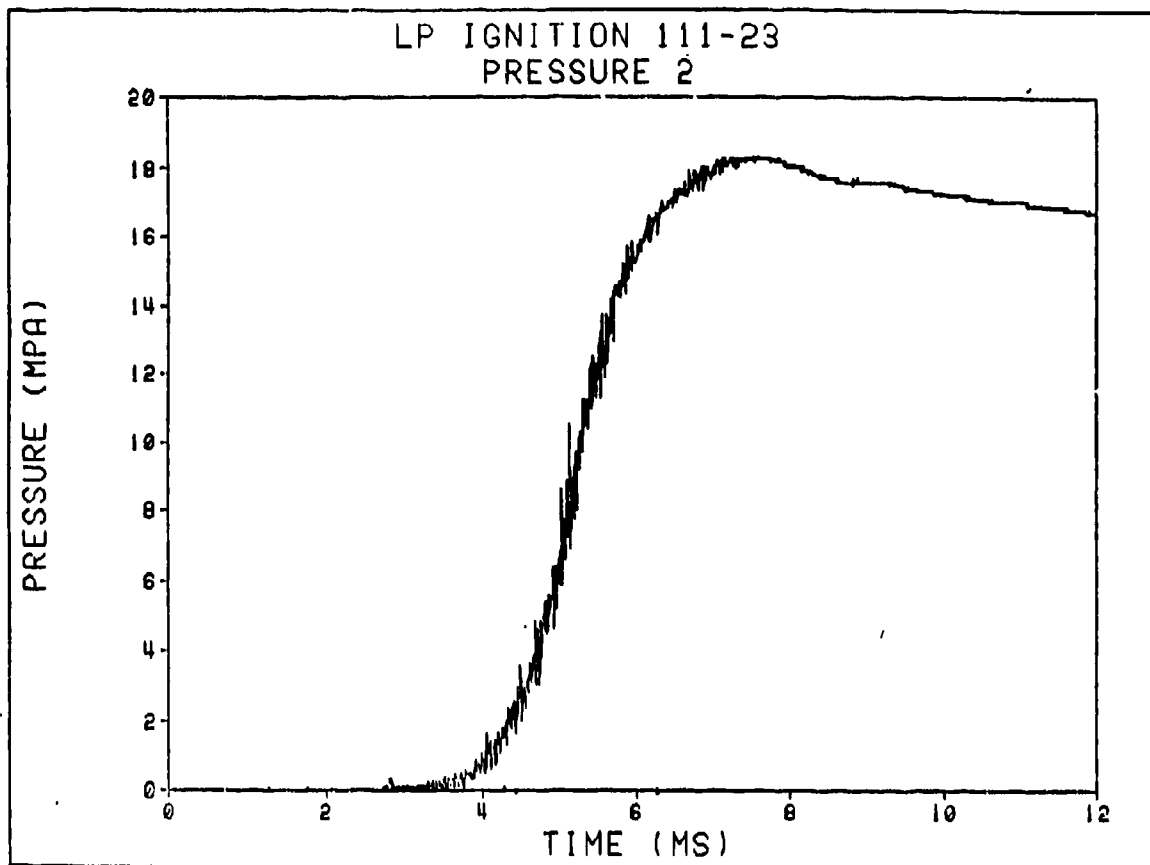


Figure 3. 106 cm³ Chamber Pressure for Reference Igniter

Tests were also performed using a slightly modified reference igniter. The only change was the substitution of a 4-mm diameter paper straw for the 6-mm diameter plastic straw. The obvious effect of this change was to substantially reduce the amount of IMR 4350 that was in the path of the M52 primer jet. The effect of the material change in the straws is unknown. There were never any parts of the straws recovered in either test. Nine tests were performed under these conditions and are summarized in Table 2. The hyphenated Ident numbers refer to pressures recorded on a Nicolet Oscilloscope rather than the ballistic data acquisition system. The lack of a pressure for Ident 1-3 was caused by a trigger adjustment problem. The percentage variation in the standard deviation for the maximum chamber pressure was significantly degraded when compared with the results from the reference igniter.

TABLE 1. Solid Propellant Igniter, 3.0 g IMR 4350,
with straw confinement (GE method).

Ident No.	Maximum Pressure igniter chamber	106 cm ³ chamber	Rate of Pressure Rise 106 cm ³ chamber	Rise Time 10-90% 106 cm ³ chamber
	MPa	MPa	MPa/ms	ms
020	141	17.6	10.0	1.7
021	-	17.2	11.1	1.5
022	127	19.0	8.3	2.1
023	138	18.2	10.0	1.8
024	143	17.6	9.5	1.9
025	144	17.2	9.1	2.0
02	143	18.4	11.1	2.0
Mean	139.3	17.89	9.87	1.86
std. dev.	6.41	0.672	1.02	0.207
% std. dev.	4.6	3.76	10.3	11.1

TABLE 2. Solid Propellant Igniter, 3.0 g IMR 4350.
(modified GE method)

Ident No.	Maximum Pressure igniter chamber	106 cm ³ chamber	Rate of Pressure Rise 106 cm ³ chamber	Rise Time 10-90% 106 cm ³ chamber
	MPa	MPa	MPa/ms	ms
002	141	17.8	10.0	1.52
005	145	16.5	8.2	1.72
008	140	19.0	10.0	1.72
003	140	19.0	10.0	1.72
013	131	17.4	10.0	1.55
1-1	128	19.0	8.2	1.61
1-2	152	17.2	8.2	1.61
1-3	-	17.1	8.2	1.72
1-9	169	14.4	9.5	1.37
Mean	143.3	17.5	9.14	1.62
std. dev.	12.8	1.49	0.91	0.12
% std. dev.	8.9	8.5	9.95	7.50

In order to simplify the configuration of the reference igniter, six tests were run in which the straw confining the IMR 4350 booster charge was eliminated. For these tests the booster charge was simply placed in the bottom of the igniter cavity with a wad of tissue paper, as used in the straw method, serving as a means of initially retaining the booster charge in the igniter cavity. The results are summarized in Table 3. The percentage variation in the standard deviation for the maximum pressure, for the large chamber, was comparable with the results obtained for the reference igniter. However, the variation in maximum pressure in the igniter chamber was significantly degraded.

TABLE 3. Solid Propellant Igniter, 3.0 g IMR 4350.
(no straw)

Ident No.	Maximum Pressure igniter chamber	106 cm ³ chamber	Rate of Pressure Rise 106 cm ³ chamber	Rise Time 10-90% 106 cm ³ chamber
	MPa	MPa	MPa/ms	ms
009	160	17.2	10.5	1.65
014	151	17.0	10.0	1.48
1-4	173	16.2	10.8	1.12
1-5	172	16.2	10.8	1.29
1-7	214	16.4	9.7	1.21
1-8	216	16.3	8.8	1.47
Mean	181	16.6	10.1	1.37
std. dev.	27.6	0.44	0.77	0.20
% std. dev.	15.2	2.64	7.67	14.4

2. LIQUID PROPELLANT BOOSTER CHARGE

Tests were also performed using liquid propellant instead of the solid propellant booster charge. Since the main RLPG charge is a liquid propellant, it was considered desirable to use liquid propellant also as the igniter booster charge. The liquid propellant selected was LGP 1846. Several configurations for containing the liquid propellant in the igniter were tested. Unless otherwise noted, the tests were conducted with the igniter venting vertically downwards.

Ten tests were performed with 2 cm³ of LGP 1846 contained in a latex bag. Different types of ties were used to close the bag and the stand-off distance between the bag and the M52 primer vent (Figure 1) was varied. In all ten tests the pressures in the igniter chamber were low enough that only a fizz type decomposition occurred. The fizz type decomposition is unacceptable for a liquid propellant igniter. Therefore, this type of containment was dropped from consideration.

A group of three tests were performed with 2 cm³ of LGP 1846 contained in three or four 6-mm plastic straws. Extreme pressure variability was recorded in the igniter chamber. As a result, the use of straws containing liquid propellant was dropped from consideration also.

The best results were obtained when the LP was allowed to sit in the igniter cavity uncontained. In this configuration, thin Mylar discs were used with silicone grease to initially seal the igniter vent passage (Figure 1) and retain the liquid propellant in the igniter chamber. Tests performed with 2.5 cm³ of liquid propellant are summarized in Table 4 and tests performed with 2.0 cm³ of liquid propellant are summarized in Table 5. Table 4 shows a rather large variation in the maximum pressure for the 106 cm³ chamber. For three tests under the same conditions, the maximum pressure varied from 14.6 to 23.7 MPa. The uniformity in the data was somewhat improved for the tests in Table 5 with a smaller liquid propellant booster charge. For five tests under the same conditions the maximum pressure in the 106 cm³ chamber varied from 13.9 to 19.4 MPa. The percentage variation in the standard deviation of about 14%, however, was poor when compared with the results from the reference igniter given in Table 1.

TABLE 4. Liquid Propellant Igniter (LGP 1846, Lot 50-4).
Volume of the liquid propellant was 2.5 cm³
(3.6 g); thickness of the Mylar was 0.005 in.

Ident No.	Maximum Pressure igniter chamber	106 cm ³ chamber	Rise Time 10-90% 106 cm ³ chamber
	MPa	MPa	ms
019*	>450	17.4	1.17
016	245	23.7	1.75
017	-	14.6	1.00
018	420	20.3	1.18
For the last three tests:			
Mean		19.5	1.31
std. dev.		4.6	0.39
% std. dev.		23.5	29.9

*Inverted Chamber-Igniter fired vertically upwards. Igniter fired vertically downwards for the other three tests.

TABLE 5. Liquid Propellant Igniter (LGP 1846, Lot 50-4).
Volume of the liquid propellant was 2.0 cm³.
(2.9 g)

Ident No.	Thickness of Mylar	Maximum Pressure igniter chamber	Pressure 106 cm ³ chamber	Rise Time 10-90% 106 cm ³ chamber
	in	MPa	MPa	ms
004	0.01	305	15.4	0.80
006	0.005	320	13.9	0.95
007	0.005	-	14.4	1.22
015	0.005	315	17.0	0.72
2-2	0.005	477	17.0	-
2-3	0.005	253	19.4	1.14
For the last five tests:				
Mean			16.3	1.01
std. dev.			2.2	0.22
% std. dev.			13.7	22.1

Several tests were performed with the igniter venting vertically upwards into the test chamber. In Ident 019, Table 4, the 2.5 cm³ of LP was again contained only with the use of the Mylar discs. However, in this case the Mylar disc was used to seal the M52 primer vent hole. In this configuration, the stand-off distance between the M52 primer vent and the liquid propellant was reduced. The igniter chamber pressure was measured in excess of 450 MPa and resulted in some minor hardware damage (the inside components of the M52 primer housing were blown out). Ident 1-10 was also fired in the inverted configuration, however, the 2 cm³ of LGP 1846 was enclosed in a latex bag with a plastic tie strap. The igniter chamber pressure for Ident 1-10 had a maximum value of 620 MPa and resulted in a primer blow out, as in Ident 019.

V. SUMMARY

The tests demonstrated the level of reproducibility which results when a pyrotechnic igniter is vented into a closed chamber. Attempts to simplify the pyrotechnic igniter using two different configurations degraded the reproducibility of the output pressure characteristics. Tests using the liquid propellant LGP 1846 as a booster charge also degraded the reproducibility characteristics when compared with the reference pyrotechnic igniter. However, the tests with the liquid propellant demonstrated a method whereby the liquid propellant can be ignited, starting at one atmosphere, and resulting in complete combustion of the liquid propellant.

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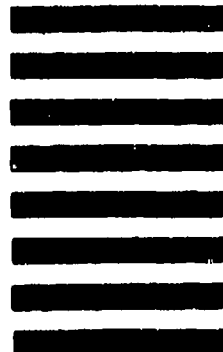
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